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Drying Technology
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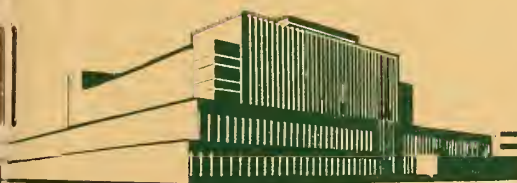
A SMALL HOUSE-FURNACE LUMBER DRY KILN

Information Reviewed and Reaffirmed

March 1956

No. 1776

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aTS837
.T673
1956



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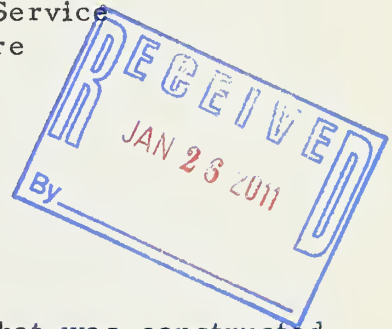
A SMALL HOUSE-FURNACE LUMBER DRY KILN¹

By

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Summary



Small furnace-type lumber dry kilns of a kind that was constructed and operated recently at the U. S. Forest Products Laboratory may be found suitable for use at many small sawmills and planing mills. The test-unit type would not be equivalent, however, to a modern-type steam-heated kiln with respect to control of temperature and relative humidity but with care in operation it would dry many species and lumber items with acceptable results, particularly if the lumber had been air dried or if it were for general constructional purposes. It employs a simple hot-air type of house furnace for heat, fans for the recirculation of the air through the lumber pile and furnace, and water sprays for humidification. Operation without fans demonstrates that a natural-circulation system of this kind does not work satisfactorily with respect to drying time and uniformity of drying, and that forced air circulation is needed. A drawing of a proposed design is presented and described.

Introduction

A great deal of water must be evaporated from green lumber in order to prevent shrinking, warping, and checking after it has been machined and put into use. The degree to which it should be dried is governed

¹The investigation of this kiln was conducted with funds provided under the Research and Marketing Act. Original report published in 1950.

²Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

by use requirements. Lumber used for boxing and crating and for general constructional purposes can often be dried to a satisfactory moisture content by air drying only. For interior use in heated buildings, however, a uniform moisture content of about 7 percent (based on the oven-dry weight of the wood) is desirable. As drying to this degree cannot be attained, in most cases, in air drying, further drying is necessary, either in a heated room or in a dry kiln. Lumber can also be kiln dried green from the saw, and in a great deal less time than by air drying. This procedure may cause even fewer seasoning defects than would occur in air drying at that particular time. Green lumber is often kiln dried when the item is of a kind that is easily and quickly dried, because the extra handling cost for both air-drying and kiln-drying operations might be overly expensive. On the other hand, particularly for difficult and slow-drying items, preliminary air drying will reduce kiln costs and, very probably, the over-all drying costs. Uniformity of moisture content and freedom from case-hardening stresses, which are essential for many uses, can be satisfactorily obtained only in a kiln where temperature and relative humidity are under good control and uniformly distributed.

For small sawmills and woodworking shops that do not have steam for dry-kiln use, there is a need for any small furnace-type kiln that is relatively cheap and simple in both construction and operation. Usually, such kilns have some limitations, and the degree of success in their operation depends a great deal upon local conditions and the ingenuity of the builder and operator. During World War II, the Forest Products Laboratory developed and tested a special sawdust-burning furnace-type kiln.³ Commercial installations of this kind of kiln have given satisfactory service, but there are, no doubt, other designs and arrangements that, for certain uses, may be simpler and more appropriate. The need for drying equipment at small sawmills and planing mills, such as those that utilize timber from farm woodlots, could be met most satisfactorily if a number of designs were available for consideration.

The principal purpose of this report is to describe a kiln having a capacity of about 4,000 board feet, in which a hot-air furnace of the pipeless type is used to supply the heat (fig. 1). Such furnaces are relatively inexpensive, readily available, and easily installed. The experimental work brought out certain disadvantages of natural air circulation as compared to forced air circulation. Unsatisfactory control of humidity conditions has always been one of the shortcomings

³-Torgeson, O. W. Furnace-type Lumber Dry Kiln. Forest Products Laboratory Report No. D1474. 1950.

of furnace-type kilns. For this reason, several methods of humidification were tried, as a result of which a water-spray arrangement within the drying compartment was selected as being the simplest and most effective.

Experimental Work

Test Unit

To save time and money, the test unit used for this study was obtained by remodeling the small experimental furnace kiln built at the Forest Products Laboratory during World War II.³ The principal changes consisted of removing the elongated heating pipes from the drying room, constructing a partition wall that divided this room into a smaller drying room and a furnace room, and installing a small 20-inch fire-pot furnace in the center of the furnace room near the partition wall, which was provided with openings for the floor-level cold-air return duct and the overhead hot-air supply duct. The design presented in figure 1 differs somewhat from the test unit. Concrete-block walls are shown in place of wood walls, external motors connected to 24-inch fans in place of the 36-inch direct-connected motor-fan units, and a small hand loading door in place of the full-size one that would be suitable for outside loading-track operation. In addition to these differences, the position of the fans, the inspection window, and the manner in which the heat pipe enters the area back of the fans, were altered slightly in the design. These changes from the test unit were made to improve the design and are considered to be relatively unimportant with respect to operating characteristics.

Factors Studied

Air circulation.--Four arrangements affecting air circulation and distribution were tested. The first was a natural-circulation system whereby the air circulated by gravity action upward through the furnace and downward through the load. This arrangement, with the furnace located to the side and on a level with the load, differs from conventional natural-circulation kilns in which the heat source is located below the load. The second arrangement was similar to the first, except that the natural circulation was assisted by a fan that greatly stimulated the air circulation by taking the air from below the load and delivering it horizontally into the furnace jacket. In the third arrangement, the kiln was converted into a typical cross-circulation fan kiln by the use of two 36-inch overhead fans with direct-connected glass-wound motors. These fans recirculated the air horizontally through the lumber pile, with a certain percentage

of the air returning to the fans by way of the furnace. The fourth arrangement was identical to the third, except for the shape of the pile. A special piling rack was installed that provided a sloping face on the entering-air side of the load. Tests made in the past have indicated that a sloping entering-air face results in somewhat more uniform distribution of air flow through the load. The rack also acts as a guide in placing the stickers so as to obtain proper spacing and good vertical alinement.

Humidification.--The humidification phase of the study consisted of testing the effectiveness of (1) water sprays, (2) absorbent cloths over perforated water pipes, and (3) a specially constructed evaporating pan on the dome of the furnace. During the drying period, advantage can be taken of the moisture evaporated from the lumber by providing a tight kiln, but at the end of the drying process it is often desirable to equalize the moisture content to some definite value and to remove casehardening stresses. To do these things, it is necessary to raise the relative humidity a great deal, sometimes to as high as 75 percent, by vaporizing and distributing a large quantity of moisture. In a steam kiln this can be done quite simply by the use of steam sprays, but in a furnace-type kiln it can be done only by supplying a vaporization system that is equivalent to the output of a small low-pressure boiler. In fact, some commercial furnace-type kilns are now equipped with a small boiler for humidification purposes only.

Operation without Fans

When the kiln was operated by natural circulation, some provisions in piling were made for the vertical movement of air through and around the load. An 18-inch space was left on the side next to the outside wall as an aid in removing kiln samples from the load during the drying process. A 6-inch space was allowed on the other side and, in addition, three 4-inch vertical flues were left within the load. These spaces, together with a 4-foot space above and a 3-foot space below the load, permitted the hot air from above, when cooled by the evaporation of the water in the wood, to drop to the cooler space below. The over-all dimensions of the pile were 6 feet wide, 16 feet long, and approximately 7 feet high. The volume of 4/4 lumber was approximately 3,500 board feet.

The kiln, however, did not work satisfactorily when operated in this manner. The results, no doubt, were poorer than would have been obtained in a conventional natural-circulation kiln where the heat source is below the load instead of on the side. Apparently, the air moved horizontally very sluggishly from the 3 foot space below the load to the 2-foot space below the base of the furnace, as is indicated by the data, collected on some 4/4 air-seasoned basswood, shown in

table 1. Basswood dries rapidly and, in a modern fan kiln, 4/4 stock should dry from 19 percent moisture content to 7 percent in about 3 days. Twelve days were required in run 1 to dry through this moisture content range, and the uniformity from top to bottom was poor, as is illustrated by the facts that the bottom samples did not start to dry until after the third day and that their average moisture content after 12 days was nearly 8 percent higher than that of the top samples. Table 1 also gives temperature data that show a tremendous temperature difference between the top, middle, and bottom portions of the load. Such differences mean that the air movement must be very slow and that, because of this, the relative humidity at the top might, in some cases, be low enough to cause checking in green lumber while high enough at the bottom to prevent drying and thus permit the development of mold and stain. Apparently, the lower part of the drying room requires heat in addition to that that comes down through the load by natural air circulation.

Operation with Furnace Fan

As the failure of the kiln to operate satisfactorily with natural air circulation was due to inadequate rates of air movement, a 24-inch high-speed fan was installed in the lower center of the partition wall so as to pull the air from below the load and deliver it to the heating space within the furnace jacket. At free delivery, this fan has a capacity of 5,500 cubic feet of air per minute, but no doubt this may have been reduced about 50 percent by losses due to resistances as the air made the circuit through furnace and load. Operation under this arrangement was fairly good, as shown by the data given in table 2.

Although some temperature differences existed within the load, samples tested with electrodes and a moisture meter indicated that towards the end of the drying period the uniformity of moisture content was fairly good throughout the load. This result may have been brought about to some extent by the fact that at the end of the run temperatures in the lower portion of the load were slightly higher than near the top which indicated that a considerable amount of hot air bypassed the top portion of the load, dropped within the 18-inch space between the wall and load, and then returned to the fan through the lower portion of the load in a more or less horizontal manner.

That the drying efficiency was a great deal better than that obtained under the natural air-circulation arrangement was indicated by the fact that in a 12-day drying period approximately 10,000 pounds of water were evaporated from the yellow-poplar compared to 1,000 pounds from the basswood. These values are not exact nor are they exactly comparable, but they do show in a general way that the added air circulation provided by the fan greatly improved the drying

efficiency. This difference in results was not due to a difference in seasoning characteristics between the two species. Yellow-poplar, being a slightly heavier wood, probably dries a little slower than basswood. Both species, however, are considered easy woods to dry.

Apparently, this furnace-fan arrangement is fairly satisfactory, particularly for air-dried stock. Nevertheless, it was felt that faster and more uniform drying could be obtained in a cross-circulation kiln and in one with greater fan capacity.

Operation with Cross-circulation Fans

The third arrangement was quite similar to that shown in figure 1. Recirculation of air horizontally through the load was provided by the two 36-inch fans used in the original unit. These fans were direct-connected to 1-1/2 horsepower motors and delivered a total of approximately 20,000 cubic feet of air per minute at 1,140 revolutions per minute. These units were overly large for a kiln of this size, but served very well to demonstrate the effect of the cross-circulation system. Such a fan system differs very little from that used in many commercial kilns. In this design, however, a part of the recirculated air returns to the fans through the furnace to carry the furnace heat into the kiln.

A run on 3/4-inch green Douglas-fir was made in 3 days under moderate temperatures and relative humidities. The temperature and air distribution were good.

Humidification

At the end of the drying process a high relative humidity treatment is necessary to relieve casehardening stresses. This treatment requires a great deal of moisture, and as no moisture is available from the lumber at that stage it must be provided by vaporizing water from an outside source.

Humidification in the Forest Products Laboratory experimental furnace kiln³ was obtained satisfactorily by spraying water onto the hot, elongated smoke pipe that served also as a radiating surface. It would not, however, be advisable to spray water onto a cast-iron dome of a furnace. Water pans are usually used in furnaces for humidification purposes, but their capacity is greatly inadequate for kiln use. An enlarged dough-shaped pan placed directly on top of the flue-gas ring also proved inadequate, mainly because too small a proportion of the furnace heat was used for evaporation. An attempt was made to remedy this by providing a bypass flue-gas duct within

the evaporating pan so as to raise the water temperature by a more direct heat-transfer method. The results, however, were not good. It was found impossible to reach a boiling temperature without providing such a hot fire that the heat output was out of proportion to that used for evaporation. It was concluded, therefore, that this humidifying method was not sufficiently effective and controllable and that only a special factory-designed-and-constructed hot-air type of furnace could satisfactorily furnish either hot air or water vapor as needed for dry-kiln operation. In other words, a special design of this kind would be such that the heat output of the furnace could be used either to heat the recirculating air or to heat and evaporate water.

Another humidifying arrangement consisted of a large number of absorbent cloths that hung over perforated water pipes with their lower ends in a pan that received the surplus water running down over the surfaces of the cloths. This apparatus was placed above the load in front of the fans, but the effect it obtained was so insufficient that it was concluded that an effective amount of cloth area would be too large to be practical.

A third and more effective method of humidification consisted of three water-spray nozzles mounted on a 1/2-inch pipe. These nozzles were located, as shown in figure 1, on the floor next to the furnace-room wall and were directed upward. Since the sprays were on the leaving-air side of the load, their direction conformed to the direction of the air flow back to the fans. Besides being a great deal more effective than the other two methods tried, water sprays are better adapted to automatic control. The most appropriate nozzle was a fan-shaped type that delivered a fine spray under a water pressure of about 50 pounds per square inch. Water pressures of 100 or 150 pounds, however, would provide an even finer and more effective mist.

Description of Proposed Kiln Design

Construction

The structure of the proposed kiln design, as shown in figure 1, consists of 12-inch concrete-block walls enclosing the drying room and 8-inch block walls enclosing the furnace room. The roof and ceiling are of wood frame construction with good provision for venting the attic space. Concrete-block walls (preferably cinder blocks for better insulation) can be kept reasonably dry by coating the inside surfaces very heavily with any asphaltic-mastic coating that is prepared especially for kiln use.

The drying room is 8 feet wide, 12 feet high, and 17 feet long. The lumber pile is about 8 feet high, 16 feet long, and 6 feet wide at the bottom and 4 feet at the top. Its maximum capacity of full length 4/4 lumber is approximately 3,800 board feet. A platform baffle rests on the I-beams 3 feet below the ceiling and directly above the load. A 2- by 4-foot opening is provided in the bottom center section of the partition wall to permit air circulation from the kiln through the furnace. This air is only part of that delivered by the fans. The major portion of the air returns directly to the fans through leaving-air space between the load and partition wall. Convection currents help the fans a great deal in stimulating air circulation through the furnace. A 3- by 8-foot loading door is lined up with the leaving-air side of the load, and near this door is an inspection door leading into the furnace room.

Two 12-inch pipe vents extend through the outside wall as outlets. Their location near the bottom of the wall is merely for convenience in adjusting the dampers and for minimizing the nuisance of the dripping of condensed moisture over the surface of the wall. The only important consideration for the outlets is that they be located on the pressure side of the fans.

The inlet, as shown in figure 1, consists of a sliding door entering into the space below the furnace. An alternate location would be in the partition wall, with one vent opening opposite each fan.

Dampers to meet the venting needs can be adjusted manually or by use of an automatic wood-element hygrostat such as was used in the experimental work,³ or of a more commercial type of automatic equipment such as a humidistat. A wet-bulb instrument can be used, provided accurate control of the dry-bulb temperature is obtainable.

Two 24-inch propeller-type fans, mounted overhead in a vertical partition or baffle, deliver the air from the furnace and from the leaving-air side of the load to the entering-air side (sloping side) of the load and then through the spaces in the load provided by the stickers. As all of this circulating air should pass through the lumber pile, it is desirable that loose or attached canvas or wooden baffles be provided to block off whatever space is left around the load. The exact size and type of fan are not important, but the total delivery of the two fans should be very nearly 10,000 cubic feet per minute. To deliver this amount of air, the motor size for each fan should be at least 1/2 horsepower. If direct-connected motor-fan units are used, the motors should be of special construction in order to perform satisfactorily under kiln temperatures and relative humidities.

A 1/2-inch water-pipe spray line extends along the bottom of the partition wall and is equipped with three spray nozzles of the kind that produces a very fine spray, preferably a flat, fan-shaped spray. These nozzles are directed upwards to conform to the direction of air flow as the air returns to the fans after passing through the load. The rate of vaporization increases with increases in the fineness of the spray, and for that reason the water pressure should be as high as permissible. Pressures much below 50 pounds per square inch do not work effectively.

The desirable size of a hot-air furnace for a kiln of 3,000 to 4,000 board-foot capacity is one that will deliver at least 150,000 (preferably more) B.t.u. of heat per hour in order to take care of fast-drying species having a high moisture content. A somewhat smaller furnace would be satisfactory for most hardwoods, especially air-dried stock, but for fast-drying species its main disadvantage would be the loss in drying time due to the use of lower temperature schedules. As shown in figure 1, the furnace is set on a base about 2 feet above the level of the floor in the drying room. In order to prevent excessive heat loss into the furnace room, the partition wall and the furnace should be well insulated. The furnace jacket in the experimental equipment consisted of asbestos insulation between a double wall of galvanized iron.

Control Equipment

The test unit was equipped with a rather small hot-air furnace having a 20-inch fire pot. It was hand-fired with Pocahontas briquets with particular attention to uniformity of heat output within the temperature range called for by the drying schedule. It was found, however, that the temperatures in the drying compartment varied considerably and that schedules could not be followed as they are in steam kilns, where dry-bulb and wet-bulb temperatures are controlled independently so as to maintain a fixed wet-bulb depression. The difficulty of humidification to control the wet-bulb temperature in furnace-kiln operation adds to the difficulty. In place of the conventional fixed-temperature control procedure, however, another control technique can be used, which consists of the use of a wood-element hygrostat^{3, 4} that controls on the basis of the equilibrium moisture content of wood. This instrument can be hooked up in several ways, but the most effective, and perhaps the simplest one is to use it to control the water sprays, together with thermostatic control of the furnace and

⁴Johnson, S. J., and Rasmussen, E. F. A Wood-element Hygrostat. Forest Products Laboratory Report No. 1602. 1946.

hand operation of the vents. The vents, of course, should be kept closed as much as possible to reduce the need of using the water sprays. The draft door of the furnace is operated by an electric damper motor actuated not only by the drying-room thermostat, but also by a dome switch in the hood of the furnace to prevent overheating in case the drying-room thermostat is set above the capacity of the furnace. Either a damper motor hooked to a spring valve or else an electric motor valve, on the water-supply line can be used for the spray line. The valve used should be connected to the micro-switch on the wood-element hygrostat through a 25-volt transformer.

If an oil burner, gas burner, or coal stoker is used, the temperature in the drying room can be kept a great deal more constant than when the furnace is hand-fired. It would be permissible, therefore, to control the wet-bulb temperature individually by means of a second electric-contact type of thermostat equipped with a water box and a wick for its bulb. This thermostat would replace the wood-element hygrostat, but it would be connected in the same manner to the valve on the water line.

Necessary parts of the control equipment are the glass-block inspection window in the center of the outside wall and the wet- and dry-bulb thermometers⁵ mounted directly inside so as to be readable from the outside. All control settings must be adjusted according to these readings. For cold weather operation, the inverted water bottle, mounted on the outside wall to supply the well or reservoir for the wick on the wet-bulb thermometer, must be enclosed or its use must be eliminated by replacing the bottle with a funnel and then refilling the well a short time before each reading is taken.

Alternate Arrangements and Equipment

Flat or Pitched Roof

A flat roof that is properly designed for strength, well insulated against heat losses, and provided with a good moisture barrier on the inside surface can be used in place of the separate ceiling and pitched-roof construction. In the case of a wood roof, it is generally undesirable to use ceiling on the underside of the roof joist unless provision is made to ventilate adequately the space between the ceiling

⁵

Using the Wet- and Dry-bulb Thermometers in Lumber Dry Kiln Work. Forest Products Laboratory Report No. 1772, May 1950.

and roof boards. The construction of various types of roofs is described in Forest Products Laboratory Report No. 1646.⁶

Wood, Brick, or Tile Walls

Walls constructed of wood are less fire-resistant and are usually considered to be shorter-lived than masonry walls. Under some conditions, however, they may be the most practical, particularly with respect to first cost, because of the local availability of material and labor. The use of the heartwood of durable species and a good moisture barrier on the inside wall surfaces would help a great deal in prolonging the life of wood structures. The moisture barrier could very well consist of 55-pound roofing paper placed vertically on the studs under the inside sheathing. All joints must be sealed. No excessive leakage of vapor must be permitted to enter insulated wooden walls and ceiling. Some leakage is unavoidable, however, and for that reason the outer wall should not be vapor tight and, preferably, should be so vented as to allow the escape of vapor and yet afford satisfactory protection from rain.

Brick or tile should be of the dense, hard-burned type laid in tempered cement mortar. Brick walls should be 13 inches in thickness and tile walls 12 inches, but in both types long kiln walls should be strengthened with pilasters not more than 20 feet apart. In some cases, tile walls are faced with brick on the outside.

Boiler for Furnace

This kiln design (fig. 1) would become a more or less conventional cross-circulation steam-kiln design by replacing the furnace with a low-pressure boiler. In this case, a fin-type radiator unit would be installed in front of each fan. The supply and return lines would be short, as would be the supply line to the steam spray pipe. The spray pipe could be a 1/2-inch pipe with 1/8-inch holes on the top side spaced about 18 inches apart. To take care of the water loss through the spray line, the water level in the boiler would have to be taken care of automatically.

Preferably, the boiler and radiators should provide a heat output of about 150,000 to 200,000 B.t.u. per hour to take care of fast-drying species such as green pine. A smaller size, however, would be

⁶
-Teesdale, L. V. Dry-kiln Building Materials and Construction. 1947.

adequate for the many hardwood species that dry more slowly under lower temperature schedules. No big allowance in size need be made for the steam sprays because, during the early stages of drying, the steam requirement for humidification is very low as compared to that needed for heating and, as drying progresses, its increase is usually less than the decrease in heating requirements. At the end of the drying when a conditioning treatment for relief of casehardening stresses is given, the major steam use is for the spray line. The amount used for heating during conditioning need not be great, and the over-all requirement in a reasonably tight kiln need not be much greater than the initial heating requirement.

In a boiler installation no air (except for venting) is recirculated outside of the drying chamber. For this reason, the boiler need not be elevated and can be placed at any convenient elevation. The furnace heat-pipe opening in the center and top portion of the partition wall could be used as the new location for the vent inlet.

Automatic or Hand Feed

The experimental runs were made by hand feeding the furnace with Pocahontas briquets. Kiln temperatures, however, were not controlled satisfactorily in this manner. Control of drying conditions was accomplished only by establishing a temperature range within which satisfactory equilibrium moisture content conditions could be brought about by vent and water-spray operation. The use of gas, oil, or stoker-fed coal under automatic control would greatly reduce this difficulty. In the previous study of furnace-type kilns, the sawdust burner, with its gravity feed of sawdust from the hopper to the grates, was found to control kiln temperatures much better than a hand-fired coal- or wood-burning furnace.

Mechanical or Hand Loading

The simplest and the lowest-in-first-cost method of loading the lumber into the kiln is to provide, as shown in the plans, a relatively small loading door and a piling foundation and guide within the kiln. Slots can be cut in the door jambs at several heights to support a car-loading type of roller. One man within the kiln can place the first board on the ends of the stickers in line with the door so that the succeeding boards can slide on it into the proper lengthwise position. They can then be shoved across the stickers into final position against the piling guides.

The kiln, however, could be loaded and unloaded more rapidly by providing a track system and kiln trucks and doing the stacking and unstacking outside. Either a loading track and transfer car and transfer track can be used, or the lumber can be piled in units wherever most convenient and then be placed on the kiln trucks, located on tracks directly in front of the kiln door, by means of a lift truck. In using the lift-truck system, the loading tracks would simply be an extension of those within the kiln, and no transfer track and car would need to be provided. In using either of these track systems, a regular-size loading door would have to be provided, and, because the entering-air side of the load would have to be vertical, the kiln capacity would thereby be somewhat reduced.

Another alternative would be to provide two full-size doors, one at one end for loading and another at the other end of the kiln for unloading. The track would extend out in both directions, so that stacking of green stock and unstacking of dry stock could proceed while the kiln was in operation. One objection to a two-door design in a small furnace-type kiln is the possibility of excessive leakage. In this case the water evaporated from the lumber becomes less effective in maintaining the proper relative humidity, and more supplemental humidification may therefore be necessary.

References

Literature available at the Forest Products Laboratory that would be helpful in the construction and operation of a furnace-type kiln, in addition to that referred to in the text of this report, is as follows:

Technical Note 186, Coatings that Prevent End Checks.

" " 213, The Detection and Relief of Casehardening.

" " 233, Approximate Air Seasoning and Kiln Drying
Periods for Inch Lumber.

Sketches ZM53512F, ZM72541F, Essential Features in Piling for Air
Seasoning.

Report No. R446, List of Publications on the Seasoning of Wood.

" " R1031, List of Dry Kiln Companies and Engineers and
Consultants in the United States.

" " R1607, Use of Kiln Samples in Operating a Lumber
Dry Kiln.

" " R1655, Moisture Content of Wood in Use.

" " TP-4, List of Manufacturers and Dealers for Log and
Lumber End Coatings and End-coating
Material.

" " TP-26, Suppliers of Temperature and Humidity Recorders,
Controllers, and Indicators, and also Dry-
kiln Doors and Door Hardware.

" " TP-49, List of Manufacturers and Dealers Handling
Apparatus for Determining Moisture Content
of Wood.

Separate from USDA Wood Handbook: Control of Moisture Content
and Shrinkage of Wood.

Report No. D1791, Schedules for Kiln Drying of Wood.

Table 1.--Kiln drying of 4/4 basswood under natural air-
circulation arrangement

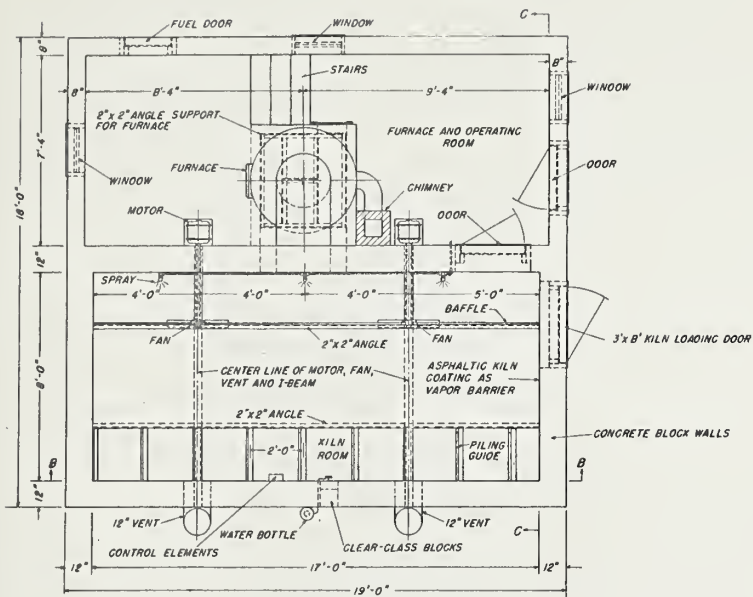
Location in load		Drying time in days						
		0	1	2	3	6	9	12
Top	:Moisture :	:	:	:	:	:	:	:
	:content :	:	:	:	:	:	:	:
	:percent :	18.2	15.3	13.0	11.6	6.6	4.4	3.5
Top	:Tempera- :	:	:	:	:	:	:	:
	: ture ¹ :	:	:	:	:	:	:	:
	: °F. :	40	160	153	167	164	160	158
Center	:Moisture :	:	:	:	:	:	:	:
	:content :	:	:	:	:	:	:	:
	:percent :	19.7	19.0	17.5	16.5	11.2	7.8	6.7
Center	:Tempera- :	:	:	:	:	:	:	:
	: ture ¹ :	:	:	:	:	:	:	:
	: °F. :	40	96	95	104	103	95	115
Bottom	:Moisture :	:	:	:	:	:	:	:
	:content :	:	:	:	:	:	:	:
	:percent :	18.9	19.2	18.5	18.7	16.1	12.6	11.2
Bottom	:Tempera- :	:	:	:	:	:	:	:
	: ture ¹ :	:	:	:	:	:	:	:
	: °F. :	40	77	77	85	78	70	93

¹—These temperature readings were taken near the kiln samples on the edge of the load nearest the outside wall. They represent very well temperature differences in other parts of the load.

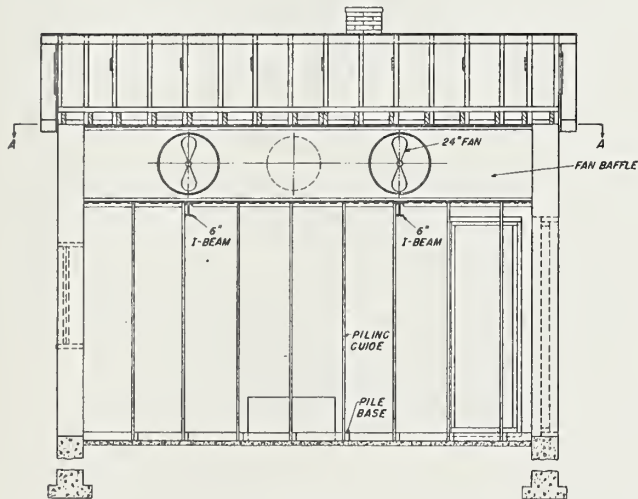
Table 2.--Kiln drying of 4/4 yellow-poplar under natural
furnace-fan arrangement

Location in load		Drying time in days						
		0	1	2	3	6	9	12
Top	:Moisture :	:	:	:	:	:	:	:
	:content :	:	:	:	:	:	:	:
	:percent :	100.9	73.0	50.2	34.9	26.5	9.5	6.4
Top	:Tempera- :	:	:	:	:	:	:	:
	: ture ¹ :	:	:	:	:	:	:	:
	: °F. :	40	115	141	144	138	138	149
Center	:Moisture :	:	:	:	:	:	:	:
	:content :	:	:	:	:	:	:	:
	:percent :	116.2	87.3	62.3	44.0	32.9	14.2	8.7
Center	:Tempera- :	:	:	:	:	:	:	:
	: ture ¹ :	:	:	:	:	:	:	:
	: °F. :	40	113	136	141	131	138	151
Bottom	:Moisture :	:	:	:	:	:	:	:
	:content :	:	:	:	:	:	:	:
	:percent :	107.9	77.0	54.6	38.6	28.9	11.1	7.1
Bottom	:Tempera- :	:	:	:	:	:	:	:
	: ture ¹ :	:	:	:	:	:	:	:
	: °F. :	40	112	136	140	131	137	151

¹These temperature readings were taken near the kiln samples on the edge of the load nearest the outside wall. In the center glue, temperature differences of about 20° F. existed between the top and bottom of the load during most of the run, but became very small near the end of the run.

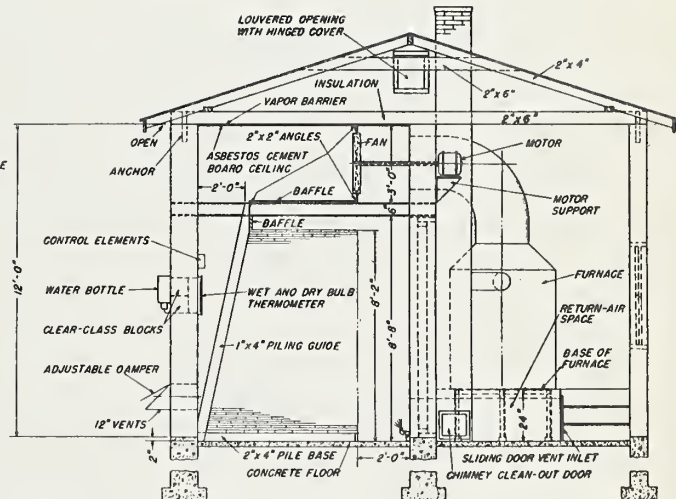


SECTION A-A



SECTION B-B

SCALE
0 1 2 3 4 5 6 FEET



SECTION C-C

Figure 1.--Small house-furnace lumber dry kiln.

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